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Foreign Technology Division
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by

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
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Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

THE EFFECT OF ALUMINUM ADDITIVES ON THE OPERATIONAL EFFECTIVENESS OF THE CATALYTIC COMBUSTION AGENT Fe_2O_3

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It is known, that the operational effectiveness of catalytic additives on the combustion rate u of mixed systems depends on a number of parameters. In works [1, 2] the dependence of the operational effectiveness of ferric oxide on the relationship α between an organic combustible and an oxidizing agent, the size of the oxidizing agent particles, pressure, and initial temperature was studied.

In this work we study the effect of aluminum additives of diverse dispersity on the operational effectiveness of the catalytic agent (1% Fe_2O_3).

Experiments were carried out with mixtures of ammonium perchlorate (APC) and potassium perchlorate (PPC) with polystyrene (PS) and polymethyl methacrylate (PMMA). The effective particle[1]

[1]The effective size was calculated with respect to the magnitude of the specific surface, measured employing a PSKh-4 instrument.

size d was APC ~9, PPC ~10, PS ~5, PMMA ~3, Fe_2O_3 ~1.8 μm. Two dispersities of aluminum were employed - fine, PAK-4 grade ($d \simeq 3$ μm, the particles were in the form of flakes) and relatively coarse ($d \simeq 20$ μm, the particles were in the form of spheres). The mixture was calculated in such a way, that the relationship between the oxidizing agent and the combustible did not vary upon the introduction of the aluminum.

The components were mixed on tracing paper with a rubber plug, wrapped in the tracing paper for over a period of an hour. Charges were pressed from the prepared mixture in small brass vessels (the internal diameter was 8 mm, the charge height h was 8-12 mm). The charges were burnt in a constant-pressure bomb in nitrogen. The combustion time was measured employing a piezoelectric quartz crystal pressure sensor. The average combustion rate was calculated. The operational effectiveness of the catalytic agent was characterized by the magnitude $Z = u/u_0$, where u and u_0 were the combustion rates of the composition with and without the catalytic agent.

Figure 1a, shows the dependence of the operational effectiveness of 1% Fe_2O_3 on the per cent of finely dispersed aluminum additive for compositions of APC + PS when $\alpha = 0.15$; 0.5, and 2.1 and at a pressure of $p = 40$ at. Points on the y-axis, which correspond to compositions without aluminum (Z_0), lie at different height, since the operational effectiveness of the catalytic agent depends greatly on α [1].

It is evident from Fig. 1a, that the introduction of finely dispersed aluminum leads to a reduction in the effectiveness of the catalytic agent both for mixtures with a surplus of oxidizing agent ($\alpha = 2.1$), and also for mixtures with a large surplus of organic combustible ($\alpha = 0.15$). It is necessary to emphasize, that for these mixtures the effect of the catalytic agent on the initial (without aluminum) composition is great ($Z_0 = 1.5$-1.8).

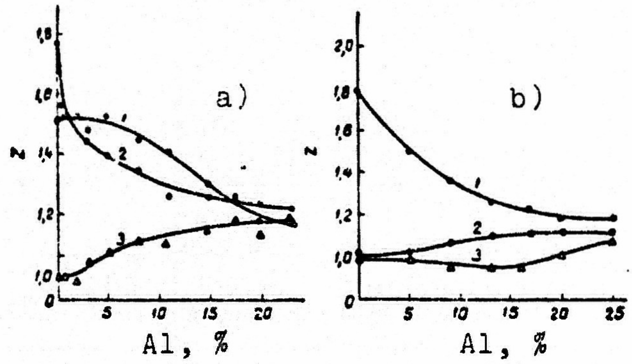

Fig. 1. The operational effectiveness of 1% Fe_2O_3 on the combustion of mixtures of APC + PS + Al depending on the per cent of aluminum with different α(p = 40 at): a) $d_{Al} \simeq$ $\simeq$ 3 μm (1 - α = 0.15; 2 - α = 2.1; 3 - α = 0.5); b) $d_{Al} \simeq$ 20 μm (1 - α = 2.1; 2 - α = 1; 3 - α = 0.5).

On the other hand, for mixtures with a small surplus of organic combustible, when a binary mixture, *oxidizing agent + + organic combustible*, has its maximum combustion rate and accordingly, its minimum magnitude Z_0, additions of finely dispersed aluminum increase the effectiveness of the catalytic agent.

With a rather large percent of aluminum (18-23%) for all mixtures the effectiveness of the catalytic agent is approximately identical and moreover is not too small (Z = 1.15-1.20), in spite of the fact, that the combustion rate of such mixtures is great (for a mixture of APC + PS, α = 2.1, with 23% Al and at a pressure of 40 at u_0 = 25.4 mm/s). For APC + PMMA compositions the very same results were obtained as for APC + PS compositions. For compositions of APC + PMMA, α = 0.61 and 2.18, for which Z_0 is great (1.6-1.8), aluminum additives reduce the operational effectiveness of the catalytic agent; on the other hand, with α = 1, when Z_0 is small (~1.2), aluminum additives do not affect the operational effect of Fe_2O_3.

Figure 1b, shows the results of experiments for compositions of APC + PS with the addition of coarsely dispersed aluminum. From a comparison of Fig. 1a, and 1b it follows, that with $\alpha = 2.1$, when Z_0 is great (~1.8), additions of coarsely dispersed aluminum, as well as additions of finely dispersed aluminum considerably reduce the magnitude of Z. For compositions, not too far from stoichiometric ($\alpha = 1$ and 0.5), when $Z_0 \simeq 1$, additions of coarsely dispersed aluminum increase Z (but more weakly than additions of finely dispersed aluminum; moreover, the increase in Z begins at a higher per cent of aluminum).

Let us now trace the variation in the absolute combustion rates of catalyzed and uncatalyzed compositions in proportion to the introduction of additions of aluminum.

Curves, showing the effect of aluminum content on combustion rate, upon the introduction of the finely dispersed metal in the majority of cases have an indentical form, independent of the composition of the mixture, the presence of a catalytic agent, pressure (Fig. 2). With small per cents of aluminum ($\leq 5\%$) the combustion rate does not increase, and in certain cases even drops. With a further increase in aluminum content the combustion rate begins to increase rapidly (especially steeply in the case of mixtures with an excess of oxidizing agent, Fig. 3a).

This dependence has another character upon the introduction of coarse aluminum (Fig. 3b). The combustion rate of mixtures of APC + PS, $\alpha = 0.5$ and 1.0, monotonically decreases in proportion to the increase in the per cent of coarse aluminum (up to 25%). When $\alpha = 2.1$ additions of coarse aluminum, although they also increase combustion rate, but more weakly than additions of fine aluminum.

Let us now dwell on the effect of the nature of the oxidizing agent. We showed earlier, that Fe_2O_3, being a rather effective

catalytic agent for mixtures based on APC, practically does not affect the combustion rate of mixtures based on PPC [3]. Experiments carried out in the course of the present investigation show, that Fe_2O_3 is also ineffective in compositions with the addition of fine aluminum (Fig. 4 for a composition of PPC + PS, α = 2). However, fine aluminum increases the combustion rate of the composition. If fine aluminum is introduced into a composition of PPC + PS (α = 2), the combustion rate is decreased. In this case Fe_2O_3 becomes effective in the sense, that for a catalyzed composition the combustion rate is reduced (in proportion to the increase in the coarse aluminum content) more weakly than for an uncatalyzed composition (Fig. 4). With a content of coarse aluminum of 20-25% the value of Z becomes equal to ~1.2.

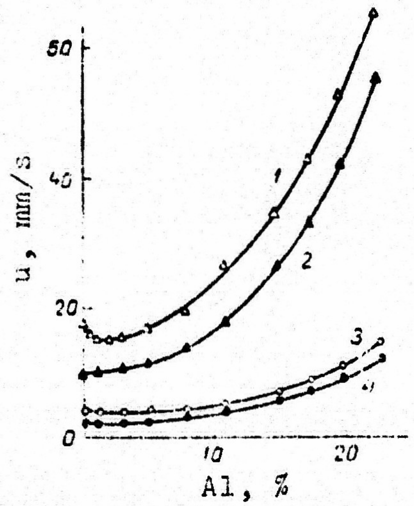

Fig. 2. The dependence of the combustion rate of a mixture of APC + + PS + PAK-4 (α = 2.1) on the per cent of aluminum: 1, 2 - p = = 100 at; 3, 4 - p = 10 at, 1, 3 - with 1% Fe_3O_2, 2, 4 - with the catalytic agent.

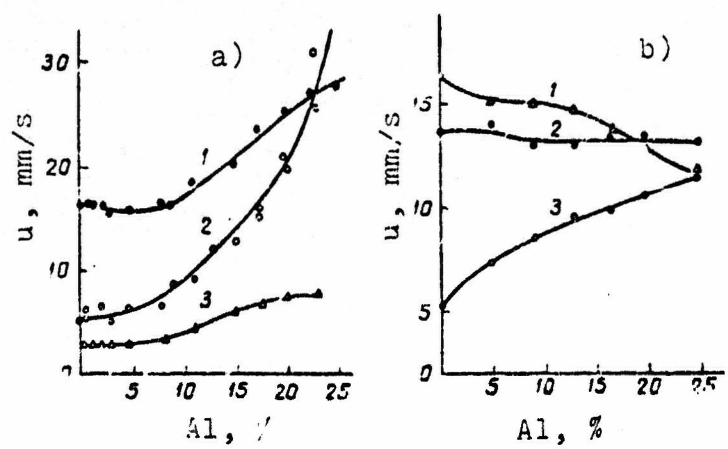

Fig. 3. The dependence of the combustion rate of mixtures of APC + PS + Al on the per cent of aluminum at different α(p = = 40 at): a) $d_{Al} \simeq 3$ μm (1 - α = 0.5; 2 - α = 2.1; 3 - α = 0.15; b) $d_{Al} \simeq 20$ μm (1 - α = 0.5; 2 - α = 1, 3 - α = 2.1).

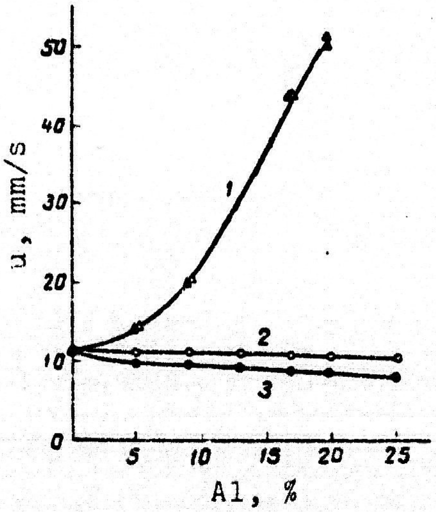

Fig. 4. Dependence of the combustion rate of a PPC + + PC + Al mixture ($\alpha = 2$) on the per cent of aluminum ($p = 40$ at): 1 - $d_{Al} \approx 3$ μm (Δ - with 1% Fe_2O_3; ▲ - without catalytic agent): 2, 3 - $d_{Al} \approx 20$ μm (2 - with 1% Fe_2O_3; 3 - without catalytic agent).

Let us now examine the physical sense of the results obtained. The conclusion was drawn in work [1], that catalytic agent effectiveness Z drops with an increase in combustion temperature ($T_г$). We saw, however, that for a number of mixtures the additions of fine aluminum (which increase u_0 and, undoubtedly, increase $T_г$) not only do not reduce, but even increase Z. In other words, it is not possible to explain the variation in the magnitude of Z upon the introduction of aluminum by the variation in $T_г$.

It is possible to assume, that with a large per cent of aluminum, when the heat release due to the combustion of aluminum particles begins to play a driving role, the effect of the catalytic agent is connected with the acceleration of the ignition and the combustion of aluminum particles. The catalytic agent can

vary the composition of the gaseous combustion products of an *oxidizing agent - organic combustible* mixture, and also vary the degree of agglomeration of metal particles on the surface of a burning charge. With an increase in the size of the aluminum particles the rate of heat release due to combustion sharply drops. Moreover, for a number of mixtures coarse aluminum behaves like an inert additive. However, in this case also, the catalytic agent can play an appreciable role, by varying the relationship between the expenditures of heat for heating the aluminum particles and the heat release due to their combustion.

CONCLUSIONS

1. The effect of aluminum additives on the operational effectiveness of the catalytic agent (1% Fe_2O_3) during the combustion of ammonium and potassium mixtures with polystyrene and polymethyl methacrylate was investigated.

2. For mixtures with a surplus of oxidizing agent or with a great excess of combustible the catalytic agent acts strongly on the initial (without aluminum) mixture, but aluminum additives reduce its effectiveness. On the other hand, for mixtures, not too far from stoichiometric, the catalytic agent acts weakly on the initial mixture, but aluminum additives increase its effectiveness.

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